



**Manchester
Metropolitan
University**

Dobbin, Nicholas ORCID logoORCID: <https://orcid.org/0000-0001-7508-1683>, Highton, Jamie, Moss, Samantha and Twist, Craig (2020) The effects of in-season, low-volume sprint interval training with and without sport-specific actions on the physical characteristics of elite academy rugby league players. *International Journal of Sports Physiology and Performance*, 15 (5). pp. 705-713. ISSN 1555-0273

Downloaded from: <https://e-space.mmu.ac.uk/623769/>

Version: Accepted Version

Publisher: Human Kinetics

DOI: <https://doi.org/10.1123/ijsp.2019-0165>

Please cite the published version

<https://e-space.mmu.ac.uk>

1 **Manuscript Title:** The effects of in-season, low-volume sprint
2 interval training with and without sport-specific actions on the
3 physical characteristics of elite academy rugby league players.
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50

Abstract

Purpose: To determine the utility of a running and rugby-specific, in-season sprint interval interventions in professional rugby league players. **Methods:** Thirty-one professional academy rugby players were assigned to a rugby-specific (SIT_{r/s}, $n = 16$) or running (SIT_r, $n = 15$) sprint interval training group. Measures of speed, power, change of direction (CoD) ability, prone Yo-Yo IR1 performance and heart rate recovery (HRR) were taken before and after the 2-week intervention as were sub-maximal responses to the prone Yo-Yo IR1. Internal, external and perceptual responses were collected during SIT_{r/s}/SIT_r, with wellbeing and neuromuscular function assessed before each session. **Results:** Despite contrasting (*possible to most likely*) internal, external and perceptual responses to the SIT interventions, *possible to most likely* within-group improvements in physical characteristics, HRR and sub-maximal responses to the prone Yo-Yo IR1 were observed after both interventions. Between-group analysis favoured the SIT_{r/s} intervention (trivial to moderate) for changes in 10 m sprint time, CMJ, change of direction and medicine ball throw as well as sub-maximal (280-440 m) high metabolic power, PlayerLoad™ and acceleratory distance during the prone Yo-Yo IR1. Overall changes in wellbeing or neuromuscular function were *unclear*. **Conclusion:** Two-weeks of SIT_{r/s} and SIT_r was effective for improving physical characteristics, HRR and sub-maximal responses to the prone Yo-Yo IR1, with no clear change in wellbeing and neuromuscular function. Between-group analysis favoured the SIT_{r/s} group, suggesting that the inclusion of sport-specific actions should be considered for in-season conditioning of rugby league players.

Keywords: rugby training, training load; responders; collision sport, shuttle sprinting

Introduction

The physical demands of rugby league require players to perform high-intensity efforts that include high-speed running, sprinting, changing direction, tackling and wrestling.¹ These characteristics are essential for players to succeed¹ and should be central to rugby league conditioning practices.² Developing the physical characteristics of rugby league players is the focus of preseason;^{3,4} thereafter emphasis is placed on recovery, technical and tactical development, and match preparations.⁵ This change in focus and reduced exposure to maximal-intensity work during training might explain the observed reductions in physical characteristics such as high-intensity intermittent running ability, sprint speed and lower-body power during the latter stages of a ~28-week season.³ Considering the importance often placed on the final stages of the season (i.e. finals), finding an effective strategy to maintain key performance characteristics could be particularly beneficial.

Low-volume sprint interval training (SIT) might be appealing during the season where players can be exposed to maximal-intensity activity through a reduced workload that also enables coaches to address technical and tactical aspects of the game.⁶ It is well-documented that SIT (~20-30 s) offers an effective strategy for inducing rapid physiological remodelling^{7,8} and increasing physical 'fitness' in athletic populations.^{6,9} Moreover, improvements in intermittent- and endurance-based exercise performance have been observed after only two weeks of SIT,^{6,10,11} and are attributed to morphological and metabolic adaptations within the skeletal muscle¹⁰⁻¹² and improved cardiorespiratory capacity.^{10,12} However, whilst SIT appears effective for promoting adaptation, current research is largely limited to soccer players.^{6,7,11} Studies have also failed to report the responses to this additional load during the intervention period, which is essential for managing the training load and determining the efficacy of SIT. The activity type should also be considered given the phase of implementation, such that SIT protocols containing metabolically demanding actions (i.e. changing direction or accelerating) and/or sport-specific actions (i.e. tackling), are likely to impose a greater systemic physiological load.^{2,13} Indeed, Dobbin et al.¹³ reported that the inclusion of an up/down action during a test of high-intensity intermittent running ability elicited small to moderate increases in $\dot{V}O_{2\text{peak}}$, $\dot{V}CO_{2\text{peak}}$, $\dot{V}E_{\text{peak}}$ and rating of perceived exertion (RPE) as well as moderate to large increases in PlayerLoad™, time at high metabolic power and acceleration loads. Whether the inclusion of an up/down action has any effect on physiological adaptation and responses to SIT remains unknown and warrants investigation given its association with running performance in rugby.¹⁴ Finally, it is important to consider players' ability to tolerate in-season SIT in order to ensure this

151 training modality incurs no detrimental effects within this
152 period.

153

154 Accordingly, this study aimed to 1) examine the effectiveness of
155 an in-season, low-volume rugby-specific and running SIT
156 intervention on the physical characteristics of elite academy
157 rugby league players; 2) determine any between-group
158 differences in internal, external and perceptual loads during the
159 SIT interventions and to document the accumulated training
160 load; and 3) explore the wellbeing and neuromuscular responses
161 to the intervention.

162

163 **Methods**

164 **Design and Participants**

165 Thirty-one elite academy rugby league players (age = 17.1 ± 1.0
166 y, stature 179.6 ± 5.8 cm, body mass 86.9 ± 5.8 kg) were
167 recruited from two Super League clubs. All players across the
168 two clubs were assigned to a rugby-specific (SIT_{r/s}, $n = 15$) or
169 running (SIT_r, $n = 16$) SIT intervention, with the minimization
170 approach used to balance both training groups for playing
171 position and rugby-specific intermittent fitness using the prone
172 Yo-Yo IR1.¹⁴

173

174 A parallel two-group, matched-work experimental design was
175 used to assess the effects of two SIT interventions on the
176 physical characteristics of academy rugby league players. The
177 intervention followed that of Macpherson and Weston⁶ and
178 involved players completing six sessions over a 2-week period
179 during the competitive season. The intervention period
180 coincided with a mid-season break in the team's fixtures (i.e.
181 week 12-14 of a 28-week season), though players completed
182 their normal training during this period. The prescribed sessions
183 replaced all conditioning practices with 24-48 hours between
184 sessions. Institutional ethics approval and informed consent
185 were obtained before starting the study.

186

187 **Procedures**

188 ***Training intervention***

189 The intervention involved six sessions over a 2-week period with
190 each session including 6 (week 1) or 8 (week 2) 30 s repetitions
191 of maximal shuttle sprinting. Both interventions required the
192 participant to complete as many shuttles as possible in the 30 s
193 with a high degree of verbal encouragement given by the lead
194 researcher. The SIT_{r/s} group were required to adopt a prone
195 position at the start of each 20 m shuttle whilst the SIT_r group
196 remained on their feet throughout. A 3-minute active recovery
197 (walking at $1.1 \text{ m}\cdot\text{s}^{-1}$) followed each 30 s repetition.

198

199 ***Outcome measures***

200 To assess the effectiveness of the intervention, a standardised
 201 testing battery¹⁵ was conducted before and after the two-week
 202 intervention period. In all, this involved completing a
 203 standardised warm-up before performing two 10- and 20-m
 204 sprints; a change of direction test on the left and right sides; two
 205 medicine ball throws; two countermovement jumps (CMJ); and
 206 a rugby-specific Yo-Yo Intermittent Recovery Test (prone Yo-
 207 Yo IR1).¹⁴ Full details of the testing battery can be found in
 208 Supplement 1.

209
 210 All testing took place at each club's own training ground at the
 211 same time of day on artificial turf and was preceded by 48 hours
 212 of no leisure- or club-based physical activity. To control for the
 213 influence of diet, participants recorded all food and fluid intake
 214 in the 3-hours before the testing sessions and were asked to
 215 refrain from caffeine consumption on the day of testing ($ES \pm$
 216 90% CL between pre- and post-testing: carbohydrate = $0.02 \pm$
 217 0.05 ; protein, = -0.02 ± 0.08 ; fat = -0.03 ± 0.07). The same
 218 researcher conducted all testing and training sessions in a
 219 standardised order with two club coaches present but who
 220 refrained from giving verbal encouragement. All participants
 221 were familiar with the testing procedures.

222 223 **Total training load quantification**

224 Players provided an RPE for all activities 30 min after training
 225 using a 10-point scale, which was then multiplied by the duration
 226 to provide a measure of training load (sRPE).¹⁶

227 **Internal, external and perceptual responses**

228 Measures of internal and external loads were collected during
 229 the pre- and post- intervention prone Yo-Yo IR1, and SIT
 230 interventions, whilst perceptual responses were collected during
 231 SIT only. Heart rate was measured continuously during the pre-
 232 and post-intervention prone Yo-Yo IR1 (Polar, FS1, Polar
 233 Electro Oy, Finland) to ascertain mean heart rate (HR_{mean}) at
 234 160, 280 and 440 m, and to compute heart rate recovery (HRR),
 235 defined as the number of beats recovered in the 60 s after
 236 cessation of the prone Yo-Yo IR1. During all SIT sessions, HR
 237 was measured for the entire session and expressed as a
 238 percentage of peak HR ($\%HR_{peak}$).

239 *****INSERT FIGURE 1 HERE*****

240 A 10 Hz microtechnology device fitted with a 100 Hz triaxial
 241 accelerometer, gyroscope and magnetometer (Optimeye S5,
 242 Catapult Innovations, Melbourne, Australia) was worn with the
 243 unit harnessed between the scapulae. Participants wore the same
 244 unit throughout the study. The available satellites and horizontal

dilution of precision were 16.7 ± 0.8 and 0.7 ± 0.1 , respectively. After the pre- and post-intervention prone Yo-Yo IR1, the data were downloaded (Sprint Version 5.1, Catapult Sports, Victoria, Australia) and analysed for PlayerLoad™ (AU), time above $> 20 \text{ W} \cdot \text{kg}^{-1}$ (HMP) and distance accelerating above $3 \text{ m} \cdot \text{s}^{-1}$ (m) at 160, 280 and 440 m. For the SIT sessions, total distance (m), time above HMP, distance accelerating above $3 \text{ m} \cdot \text{s}^{-1}$ (m) and mean speed (%peak speed from 20 m sprint test using GPS) were analysed.

Before the intervention, participants were habituated to the CR100® scale and educated about the purpose of differential RPE (dRPE). With this knowledge, players were asked to differentiate between central (i.e. breathlessness [dRPE-B]) and local (i.e. legs [dRPE-L]) ratings of exertion 15 to 30 minutes after each SIT_{r/s} and SIT_s session and on their own. To eliminate order effect, players provided ratings in a randomised order across the sessions.

Psychometric questionnaire and neuromuscular function

Players provided ratings of perceived fatigue, soreness, sleep quality, mood and stress using a 1-5 Likert scale before each session. All players were familiar with the questionnaire and were asked to complete this away from teammates and coaches. Neuromuscular function was assessed during a CMJ using the same procedures described in Supplement 1.

Statistical analysis

Within-group changes were analysed using a post-only crossover spreadsheet,¹⁷ and between-group changes analysed using a pre-post parallel-groups spreadsheet¹⁷ with the uncertainty of estimates expressed as 90% confidence intervals (90% CL). In analysing the changes in testing battery scores, and the change in CMJ and wellbeing between groups over time, we used the baseline (pre-intervention/session 1) variable as a covariate to control for baseline imbalances between groups. The SD of individual responses (within-subject variation) was determined using the pre-post parallel-groups.¹⁷ To provide an interpretation of the magnitude of change, effect sizes (ES) were calculated as the difference between trials divided by the pooled SD derived from both interventions and the following thresholds applied: 0.0-0.2, *trivial*; 0.2-0.6, *small*; 0.6-1.2, *moderate*; 1.2-2.0, *large*; >2.0 , *very large*.¹⁸ Changes were determined mechanistically with inferences qualified using the following scale: 25% to 75%, *possibly*; 75% to 95%, *likely*; 95% to 99.5%, *very likely*; and $>99.5\%$, *most likely*.¹⁹ In instances when the confidence limits overlapped both substantially positive and negative thresholds, the change was interpreted as unclear.

Results

Within- and between-group analysis on physical characteristics and HRR are presented in Table 1. Between-group differences were trivial for CMJ, change of direction time and medicine ball throw distance; small for 10 m sprint time; and unclear for 20 m sprint time, prone Yo-Yo IR1 distance and HRR. No clear differences were observed for the SD of the individual responses between SIT_r and $SIT_{r/s}$ for 10 m (0.03 ± 0.05 s), 20 m (0.04 ± 0.05 s), CMJ (0.01 ± 0.01 s), change of direction (0.08 ± 0.23 s), medicine ball throw (-0.1 ± 0.2 m) prone Yo-Yo IR1 (47 ± 92 m) and HRR (3 ± 5 b·min⁻¹).

****INSERT TABLE 1 HERE****

Sub-maximal internal and external responses during the prone Yo-Yo IR1 along with within-group and between-group analysis are presented in Table 2. Results revealed trivial to small positive within-group changes in HR_{mean} and a trivial between-group difference at 160 m. Small to very large within-group changes were observed in time spent at HMP, PlayerLoad™, and distance accelerating above 3 m·s⁻¹, with unclear to moderate between-group differences. No clear differences were observed for the SD of the individual responses between SIT_r and $SIT_{r/s}$ for HR at 160 m (3 ± 3 b·min⁻¹), 280 m (-2 ± 4 b·min⁻¹) and 440 m (2 ± 3 b·min⁻¹), HMP at 160 m (0.6 ± 1.4 s) and 280 m (-0.7 ± 0.7 s), PlayerLoad™ at 280 m (-0.8 ± 0.9 AU) and 440 m (-0.7 ± 1.0 AU) and distance accelerating at 160 m (-0.7 ± 1.0 m), 280 m (0.4 ± 1.2 AU) and 440 m (-0.5 ± 1.1 AU). The SD of individual responses to $SIT_{r/s}$ was *most likely* greater for HMP at 440 m (1.4 ± 0.6 s) and *very likely* lower for PlayerLoad™ at 160 m (-1.3 ± 0.7 AU).

****INSERT TABLE 2 HERE****

Training load across the intervention period is presented in Figure 1, with unclear between-group differences observed across all sessions for skills ($ES \pm 90\% CL = 0.06 \pm 0.51$), SIT (0.04 ± 0.30) and resistance training (0.05 ± 0.31). Moderate differences in the response to $SIT_{r/s}$ and SIT_r were observed for distance (108.6 ± 12.7 cf. 118.3 ± 10.2 m), time at HMP (17.2 ± 2.3 cf. 14.6 ± 2.5 s) and distance accelerating above 3 m·s⁻¹ (9.0 ± 3.0 cf. 7.0 ± 2.0 m). A very large difference in mean speed was observed between $SIT_{r/s}$ and SIT_r (60.3 ± 3.5 cf. 67.6 ± 4.0 %peak speed). Small differences were observed between $SIT_{r/s}$ and SIT_r in HR_{mean} (154 ± 9 cf. 151 ± 12 b·min⁻¹), dRPE-L (74 ± 14 cf. 74 ± 13 AU) and dRPE-B (65 ± 18 cf. 62 ± 13 AU) (Figure 2).

****INSERT FIGURE 2 HERE****

Small to moderate reductions in perceived wellbeing were observed during the intervention period (ES -0.23 to -1.02); albeit with no clear mean difference between session 1 and 6 (Figure 3). Neuromuscular function demonstrated a trivial to small reduction across the intervention period (ES = -0.52 to 0.28) with no clear mean difference between session 1 and 6 (Figure 3).

****INSERT FIGURE 3 HERE****

Discussion

The aim of the current study was to investigate the effects of two sprint interval interventions on the physical characteristics, wellbeing and neuromuscular function of academy rugby league players when conducted in-season. The internal, external and perceptual response to training indicated that both interventions were very high-intensity training modalities; SIT_{r/s} elicited a greater metabolic load, whilst the SIT_r group covered greater distance at a higher mean speed. Both interventions were effective for eliciting positive changes in the physical characteristics, HRR and the submaximal responses to the prone Yo-Yo IR1 with few clear differences in the SD of the individual responses. Between-group analysis favoured the SIT_{r/s} for some characteristics despite similar absolute training loads across the intervention. Overall mean change in wellbeing and neuromuscular function were unclear.

The within-group mean improvements in sprint, CMJ, change of direction and medicine ball throw performance contrast previous observations demonstrating no clear effect of 3 to 7 weeks of SIT on power-, force- and speed-based actions.^{7,20} Our results do agree with studies that have used repeated sprint training with mean improvements in all outcome measures,^{21,22} though the observed mean change for 10 m, 20 m, CMJ, change of direction and medicine ball throw in this study were less than the required change noted by Dobbin et al.¹⁵. Nonetheless, the small to moderate within-group changes might be explained by muscular adaptation, including an increase in substrate (i.e. phosphocreatine), enzymatic activity^{7,8} and alteration of contractile properties,²³ as well as potential neural adaptations (i.e. fibre recruitment, firing rate, motor unit synchronisation, recruitment of the gluteal muscle group).^{21,22} Results indicate that exposure to maximal speed and emphasis on accelerated running, particularly during SIT_{r/s}, constitutes an important element for improving power-, force, and speed-based actions,²² and likely explains the trivial to small between-group differences in favour of SIT_{r/s} for 10 m sprint, CMJ, change of direction and medicine ball throw performance. Practitioners might consider including sport-specific actions in conjunction with SIT to

390 maximise adaptation in power-, force- and speed-orientated
 391 characteristics in rugby league players.

392
 393 Both interventions appeared equally as effective for eliciting
 394 improvements in prone Yo-Yo IR1 performance with the mean
 395 change in $SIT_{r/s}$ (120 m) and SIT_r (112 m) being similar to the
 396 required change of 120 m noted by Dobbin et al.¹⁵ Such finding
 397 are important given its relationship with the internal and external
 398 responses to simulated match-play.¹⁴ These results reaffirm the
 399 small to large improvements in Yo-Yo IR1 performance after
 400 SIT and/or repeated sprint training in team-sport athletes.^{6,9,21}
 401 Although not directly measured, the improvement in total
 402 distance covered are potentially explained by several central and
 403 peripheral adaptations that promote oxygen delivery and uptake
 404 as well as mitochondrial enzyme activity, protein content (i.e.
 405 monocarboxylate transport 1 and Na^+/K^+ pump subunit β_1),
 406 muscle lactate and H^+ regulation capacity and phosphocreatine
 407 and muscle glycogen stores, amongst others; all of which likely
 408 delayed the onset of fatigue during the prone Yo-Yo IR1.^{8,12} Two
 409 weeks of high intensity training might also have increased
 410 exercise-induced pain tolerance that contributed to participants
 411 willingly extending their running time at maximal intensity
 412 during the second Yo-Yo IR1.²⁴ For example, O'Leary et al.²⁷
 413 demonstrated that 6 weeks of high-intensity exercise increased
 414 pain tolerance through greater central tolerance of nociception,
 415 and was positively associated with time to exhaustion during a
 416 cycling test. Further work is required to elucidate the
 417 mechanisms that contribute to improve high intensity
 418 intermittent running performance after short-term sprint interval
 419 training interventions in team sport athletes.

420
 421 Improvements in sub-maximal HR_{mean} and HRR in both $SIT_{r/s}$
 422 and SIT_r are associated with improvements in cardiorespiratory
 423 fitness²⁵ including increases in stroke volume, cardiac output,
 424 blood volume¹² and reductions in sympathetic activity.²⁵ The
 425 mean change in HRR was similar to Buchheit et al.²⁵ after 10
 426 weeks of high-intensity training in adolescent soccer players
 427 (60.0 ± 12.2 cf. 75.6 ± 13.6 $b \cdot min^{-1}$). Such findings indicate that
 428 both interventions induced an increase in parasympathetic
 429 reactivation and sympathetic withdrawal at exercise cessation.²⁵
 430 Sub-maximal responses during the prone Yo-Yo IR1 also
 431 suggest that $SIT_{r/s}$ appears to have enhanced the neuromuscular
 432 adaptation that might explain the trivial to moderate between-
 433 group differences in the time spent at HMP and small between-
 434 group differences in distance accelerating above $3 m \cdot s^{-1}$. From
 435 an applied perspective, this finding might encourage
 436 practitioners and coaches in rugby league to incorporate such
 437 actions within conditioning practices in an attempt to develop
 438 rugby players' ability to get up from the floor quickly, which in

439 turn might reduce the external loads (i.e. acceleratory distance)
 440 placed on players during intermittent running

441

442 Whilst our results support the notion that SIT_{r/s} and SIT_r are
 443 effective training modalities for promoting the physical
 444 characteristics of rugby league players, a key purpose of this
 445 study was to explore the efficacy of this during the competitive
 446 season. Our results for wellbeing and neuromuscular function
 447 revealed likely to most likely reductions during session two,
 448 which reflects the introduction of novel high-intensity activity
 449 during a period where maximal intensity training is typically
 450 limited.⁵ However, it is important to note that the mean change
 451 in wellbeing and neuromuscular function were unclear between
 452 sessions 1 to 6, indicating that 2-weeks sprint interval training
 453 can be incorporated in-season without residual neuromuscular
 454 and perceptual fatigue.

455

456 This study builds on the existing literature and addresses a
 457 number of the limitations previously noted. For example, a
 458 detailed insight into the accumulated training load across the two
 459 weeks enables practitioners to understand the required exercise
 460 dose to elicit the improvements observed. The intervention was
 461 also included within each team's current training schedule with
 462 only field-based conditioning replaced by SIT_{r/s} or SIT_r; thus
 463 increasing the ecological validity of this study. Furthermore, our
 464 study included measures of neuromuscular function and
 465 wellbeing throughout the training period that have not been
 466 considered previously. There are, however, several limitations
 467 that warrant acknowledgement. We were unable to include a
 468 control group in this study that completed only their normal
 469 training, meaning the effectiveness of SIT_{r/s} and SIT_r beyond
 470 their usual conditioning remains unknown. We were also unable
 471 to determine whether the change in physical characteristics
 472 positively influenced a player's match performance. However,
 473 given the relationship between tests of physical characteristics
 474 and match-play performance,¹⁴ we anticipate both interventions
 475 would offer several benefits to enhance match performance. We
 476 also acknowledge that, when taking into account the reliability
 477 of the outcome measures, the sample size required for adequate
 478 precision in change of mean is likely greater than that used in
 479 this study and may at risk of type I or type II errors. However,
 480 the sample size is in accordance with previous research and
 481 raises questions regarding the reliability of the performance tests
 482 used despite reflecting the 'typical' noise practitioners are likely
 483 to observed in rugby league academy players. Whilst the
 484 inclusion of repeated trials conducted pre- and post-intervention
 485 might be one method to reduce this noise, this is likely to be
 486 impractical in the applied setting, particularly when conducting
 487 research in-season. Finally, the intervention coincided with a
 488 mid-season period of no fixtures for the two clubs, so whether

489 SIT_{r/s} and SIT_r are suitable when combined with weekly matches
 490 is unclear.

491

492 **Practical Applications**

493 Between-group analysis supports the inclusion of sport-specific
 494 actions in the attempt to increase the systemic loads of SIT
 495 training and promote greater adaptation for physical
 496 characteristics and sub-maximal responses to intermittent
 497 running. Such findings should encourage practitioners to
 498 consider including sport-specific, metabolically demanding
 499 actions such as the up/down action used in this study within
 500 current training practices in rugby league. Furthermore, we
 501 highlight how repeated shuttle sprinting can provide a stimulus
 502 that reduced the acceleratory responses to rugby-specific
 503 prolonged high-intensity intermittent running and therefore
 504 emphasis placed on accelerating, decelerating and changing
 505 direction should be incorporated into future training practices.
 506 Finally, our results also revealed that incorporating SIT training
 507 within the competitive season is feasible without compromising
 508 athlete wellbeing or neuromuscular function, and should be
 509 consider by practitioners, particularly during the latter stages
 510 where some physical characteristics might deteriorate.³

511

512 **Conclusions**

513 In conclusion, SIT_{r/s}, and to a lesser extent SIT_r, are effective in-
 514 season micro-dosing strategies for improving a range of physical
 515 characteristics important in rugby league. Furthermore, the
 516 inclusion of SIT during the season and when combined with
 517 players' normal training routine did not elicit detrimental
 518 reductions in wellbeing and neuromuscular function. Therefore,
 519 SIT_{r/s} and SIT_r are effective training modalities that can be used
 520 to promote the physical characteristics of elite academy rugby
 521 league players in-season with similar variability in the response
 522 likely to be observed.

523

524 **References**

- 525 1. Gabbett TJ, Gahan CW. Repeated high-intensity effort
 526 activity in relation to tries scored and conceded during rugby
 527 league match-play. *Int J Sports Physiol Perform*
 528 2016;11(4):530-534.
- 529 2. Mullen T, Highton J, Twist C. The internal and external
 530 responses to a forward-specific rugby league simulation
 531 protocol performed with and without physical contact. *Int J*
 532 *Sports Physiol Perform* 2015;10(6):746-753.
- 533 3. Dobbin N, Highton J, Moss SL, *et al.* Factors affecting the
 534 anthropometric and physical characteristics of elite academy
 535 rugby league players: a multi-club study. *Int J Sports Physiol*
 536 *Perform* doi: 10.1123/ijsp.2018-0631.

- 537 4. Dobbin N, Gardner A, Daniels M, *et al.* The influence of
538 preseason training phase and training load on body
539 composition and its relationship with physical qualities in
540 professional junior rugby league players. *J Sports Sci* 2018;
541 36(24):2778-2786.
- 542 5. Gabbett TJ. Influence of training and match intensity on
543 injuries in rugby league. *J Sports Sci* 2004;22(5):409-417.
- 544 6. Macpherson TW, Weston M. The effect of low-volume
545 sprint interval training on the development and subsequent
546 maintenance of aerobic fitness in soccer players. *Int J Sports*
547 *Physiol Perform* 2015;10(3):332-338.
- 548 7. Iaia FM, Fiorenza M, Perri E, *et al.* The effect of two speed
549 endurance training regimes on performance of soccer
550 players. *PLoS One* 2015;10(9):e0138096.
- 551 8. Fransson D, Nielsen TS, Olsson K, *et al.* Skeletal muscle and
552 performance adaptation to high-intensity training in elite
553 male soccer players: speed endurance runs versus small-
554 sided games training. *Eur J Appl Physiol* 2018;1118(1):111-
555 121.
- 556 9. Ferrari Bravo D, Impellizzeri FM, Rampinini E, *et al.* Sprint
557 vs. interval training in football. *Int J Sports Med*
558 2008;29(8):668-674.
- 559 10. Burgomaster KA, Hughes SC, Heigenhauser GJ, *et al.* Six
560 session of sprint interval training increases muscle oxidative
561 potential and cycle endurance capacity in humans. *J Appl*
562 *Physiol* 2005;98(6):1985-1990.
- 563 11. Thomassen M, Christensen PM, Gunnarsson TP, *et al.* Effect
564 of 2-wk intensified training and inactivity on muscle Na⁺-
565 K⁺ pump expression, phospholemman (FXYP1)
566 phosphorylation and performance in soccer players. *J Appl*
567 *Physiol* 2010;108(4):898-905.
- 568 12. MacInnes MJ, Gibala MJ. (Physiological adaptations to
569 interval training and the role of exercise intensity. *J Physiol*
570 2017;595(9):2915-2930.
- 571 13. Dobbin N, Moss SL, Highton J, *et al.* An examination of a
572 modified Yo-Yo test to measure intermittent running
573 performance in rugby. *Eur J Sport Sci* 2018;18(8):1068-
574 1076.
- 575 14. Dobbin N, Highton J, Moss SL, *et al.* Concurrent validity of
576 a rugby-specific Yo-Yo intermittent recovery test (level 1)
577 for assessing match-related running performance. *J Strength*
578 *Cond Res* 2018; doi: 10.1519/JSC.0000000000002621.
- 579 15. Dobbin N, Hunwicks R, Highton J *et al.* A reliable testing
580 battery for assessing physical qualities of elite academy
581 rugby league players. *J Strength Cond Res*
582 2018;32(11):3232-3238.
- 583 16. Foster C, Florhaug JA, Franklin J *et al.* A new approach to
584 monitoring exercise training. *J Strength Cond Res*
585 2001;15(1):109-115.

- 586 17. Hopkins WG. Spreadsheets for analysis of controlled trials,
 587 crossovers and time series. *Sportscience* 2017;21:1-4
 588 (sportsci.org/2017/wghxls.htm).
- 589 18. Hopkins, WG. A scale of magnitudes for effect statistics.
 590 *Sportscience* 2002: Available at:
 591 <http://www.sportsci.org/resource/stats/effectmag.html>.
- 592 19. Batterham AM, Hopkins WG. Making meaningful
 593 inferences about magnitudes. *Int J Sports Physiol Perform*
 594 2006;1(1):50-57.
- 595 20. Buchheit M, Mendez-Villanueva A, Quod M, *et al*.
 596 Improving acceleration and repeated sprint ability in well-
 597 trained adolescent handball players: speed versus sprint
 598 interval training. *Int J Sports Physiol Perform*
 599 2010;5(2):152-164.
- 600 21. Taylor JM, Macpherson TW, McLaren SJ, *et al*. Two weeks
 601 of repeated-sprint training in soccer: to turn or not to turn?
 602 *Int J Sports Physiol Perform* 2016;11(8):998-1004.
- 603 22. Iaia FM, Fiorenza M, Larghi L, *et al*. Short- or long-rest
 604 interval during repeated-sprint training in soccer. *PLoS One*
 605 2017;12(2):e0171462.
- 606 23. Ross A, Leveritt M. Long-term metabolic and skeletal
 607 muscle adaptation to short-sprint training: implications for
 608 sprint training and tapering. *Sports Medicine*
 609 2001;31(15):1063-1082.
- 610 24. O'Leary TJ, Collett J, Howells K, *et al*. High but not
 611 moderate-intensity endurance training increases pain
 612 tolerance: a randomised trial. *Sport Med* 2017; 117: 2201-
 613 2210.
- 614 25. Buchheit M, Millet GP, Parisy A, *et al*. Supramaximal
 615 training and postexercise parasympathetic reactivation in
 616 adolescents. *Med Sci Sports Exerc* 2008;40(2):362-371.
- 617
- 618
- 619
- 620
- 621
- 622
- 623
- 624
- 625

Table 1. Outcome measures at baseline with the mean change and qualitative inference for the within- and between-group comparisons.

	SIT _{r/s} (<i>n</i> = 15)			SIT _r (<i>n</i> = 16)			Group Comparison	
	Baseline	Change in score (mean \pm SD; \pm 90%CL)	Qualitative inference	Baseline	Change in score (mean \pm SD; \pm 90%CL)	Qualitative inference	Between-group difference (mean; 90%CL)	Qualitative inference
10 m sprint (s)	1.76 \pm 0.08	-0.07 \pm 0.05; \pm 0.03	Moderate +ve***	1.78 \pm 0.08	-0.05 \pm 0.04; \pm 0.02	Small +ve***	0.02; \pm 0.03	Small* favouring SIT _{r/s}
20 m sprint (s)	3.02 \pm 0.11	-0.07 \pm 0.06; \pm 0.03	Moderate +ve***	3.05 \pm 0.10	-0.06 \pm 0.05; \pm 0.02	Small +ve***	0.01; \pm 0.03	Unclear
CMJ flight time (s)	0.58 \pm 0.04	0.02 \pm 0.01; \pm 0.01	Small +ve**	0.58 \pm 0.03	0.01 \pm 0.01; \pm 0.01	Small +ve****	-0.01; \pm 0.01	Trivial*
Change of direction (s)	19.79 \pm 0.71	-0.37 \pm 0.25; \pm 0.11	Small +ve***	19.53 \pm 0.60	-0.35 \pm 0.24; \pm 0.11	Small +ve***	0.02; \pm 0.15	Trivial**
Medicine ball throw (m)	7.5 \pm 0.8	0.2 \pm 0.2; \pm 0.1	Small +ve**	7.6 \pm 0.7	0.2 \pm 0.2; \pm 0.1	Small +ve**	0.0; \pm 0.13	Trivial**
Prone Yo-Yo IR1 (m)	821 \pm 215	120 \pm 103; \pm 46	Small +ve***	863 \pm 266	112 \pm 92; \pm 41	Small +ve***	-8; \pm 60	Unclear
HRR (b·min ⁻¹)	20	8 \pm 5; \pm 2	Large +ve****	21 \pm 5	8 \pm 5; \pm 2	Large +ve****	0.02; \pm 3.04	Unclear

Abbreviations: SIT_{r/s}, rugby-specific sprint interval training; SIT_r, running only sprint interval training; CMJ, countermovement jump; HRR, heart rate recovery.

Notes: Data presented as mean \pm standard deviation. Within-group comparison: +ve, beneficial (positive) effect; -ve, harmful (negative) effect. Between-group comparison: +ve, beneficial (positive) effect of SIT_{r/s} when compared to SIT_r; -ve, harmful (negative) effect of SIT_{r/s} when compared to SIT_r. * *possibly* (25-75%), ** *likely* (75-95%), *** *very likely* (95-99.5%), **** *most likely* (> 99.5%).

Table 2. Sub-maximal internal and external response during the prone Yo-Yo IR1 at baseline with mean change and qualitative inference for the within- and between-group comparisons.

	SIT _{r/s} (n = 15)			SIT _r (n = 16)			Group Comparison	
	Baseline	Change in score (mean \pm SD; \pm 90%CL)	Qualitative inference	Baseline	Change in score (mean \pm SD; \pm 90%CL)	Qualitative inference	Between-group difference (mean; \pm 90%CL)	Qualitative inference
HR _{mean} (b·min ⁻¹)								
160 m	168 \pm 7	-3.4 \pm 3.0; 1.3	Small +ve***	166 \pm 13	-2.7 \pm 3.8; 1.7	Trivial*	0.7; \pm 2.1	Trivial**
280 m	183 \pm 6	-2.6 \pm 3.7; 1.7	Small +ve**	181 \pm 9	-2.6 \pm 4.3; 1.9	Small +ve*	0.1; \pm 2.5	Unclear
440 m	189 \pm 5	-2.8 \pm 3.4; 1.6	Small +ve**	186 \pm 8	-2.7 \pm 3.0; 1.4	Small +ve**	0.1; \pm 2.0	Unclear
Time > HMP (s)								
160 m	17.2 \pm 1.9	-1.9 \pm 1.5; 0.7	Moderate +ve****	17.4 \pm 1.8	-1.7 \pm 1.4; 0.6	Moderate +ve****	0.2; \pm 0.9	Unclear
280 m	17.8 \pm 1.3	-1.3 \pm 0.6; 0.3	Moderate +ve****	17.6 \pm 1.9	-1.1 \pm 0.9; 0.6	Small +ve***	0.2; \pm 0.5	Trivial*
440 m	22.8 \pm 1.1	-2.2 \pm 1.5; 0.8	Large +ve****	21.4 \pm 1.4	-1.2 \pm 0.9; 0.3	Moderate +ve****	1.0; \pm 0.9	Moderate** favouring SIT _{r/s}
PlayerLoad™ (AU)								
160 m	20.3 \pm 2.5	-0.6 \pm 0.8; 0.4	Trivial*	20.6 \pm 2.6	-0.5 \pm 1.5; 0.7	Small +ve*	0.0; \pm 0.7	Unclear
280 m	15.4 \pm 2.6	-0.8 \pm 0.9; 0.4	Small +ve**	15.8 \pm 2.0	-0.6 \pm 1.1; 0.5	Small +ve*	0.2; \pm 0.6	Trivial**
440 m	20.5 \pm 2.9	-1.5 \pm 1.0; 0.4	Small +ve***	21.3 \pm 2.2	-0.9 \pm 1.2; 0.5	Small +ve**	0.6; \pm 0.7	Small* favouring SIT _{r/s}
Accel. > 3 m·s ⁻¹ (m)								
160 m	7.6 \pm 1.1	-2.4 \pm 1.0; 0.4	Very large +ve****	7.5 \pm 1.4	-1.8 \pm 1.1; 0.5	Large +ve****	0.6; \pm 0.6	Small** favouring SIT _{r/s}
280 m	7.0 \pm 1.4	-2.4 \pm 1.3; 0.8	Large +ve****	6.9 \pm 1.5	-1.9 \pm 1.3; 0.7	Moderate +ve****	0.6; \pm 0.8	Small* favouring SIT _{r/s}
440 m	8.1 \pm 1.5	-1.9 \pm 1.1; 0.5	Large +ve****	7.9 \pm 1.4	-1.4 \pm 1.2; 0.5	Moderate +ve****	0.5; \pm 0.7	Small* favouring SIT _{r/s}

Abbreviations: SIT_{r/s}, rugby-specific sprint interval training; SIT_r, sprint interval training; HR_{mean}, mean heart rate; HMP, high metabolic power; Accel., acceleration

Notes: Data presented as mean \pm standard deviation. Within-group comparison: +ve, beneficial (positive) effect; -ve, harmful (negative) effect. Between-group comparison: +ve, beneficial (positive) effect of SIT_{r/s} when compared to SIT_r; -ve, harmful (negative) effect of SIT_{r/s} when compared to SIT_r. * *possibly* (25-75%), ** *likely* (75-95%), *** *very likely* (95-99.5), **** *most likely* (> 99.5%).

626 Figure 1. Schematic showing training load for all resistance,
 627 rugby and sprint interval sessions across the two-week
 628 intervention.

629

630 Figure 2. Between-group differences in internal, external and
 631 perceptual responses to the SIT_{r/s} and SIT_r interventions. The
 632 whiskers-box plots represent the 25th-75th percentile of results
 633 inside the box; the median is indicated by the horizontal line
 634 across the box and the mean by a solid black circle. The whiskers
 635 on each box represent the 5th-95th percentile of results. * *possibly*
 636 (25-75%), ** *likely* (75-95%), *** *very likely* (95-99.5), ****
 637 *most likely* (> 99.5%).

638

639 Figure 3. Mean \pm SD daily perceived wellbeing (circles) and
 640 countermovement flight time (bars) for the SIT_{r/s} (light grey) and
 641 SIT_r (dark grey). * *possibly*, ** *likely* (75-95%), *** *very likely*
 642 (95-99.5%) within-group change. # possible between-group
 643 difference.